UNCERTAINTY ANALYSIS OF BALLSCREW NUT STIFFNESS

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INTRODUCTION

A ballscrew consists of a screw shaft, nuts and balls. Balls rotate between the screw shaft and nut, and convert the rotation to linear motion or vice versa. It has small driving torque and moves precisely due to rolling contact. Using preload, backlash is eliminated and its stiffness is increased. Fig. 1 shows a preloaded double-nut ballscrew. Positioning accuracy is subject to its nut stiffness. Hertzian deformation of balls and grooves as well as body deformation of screw shaft and nut according to thrust force, preload and groove characteristics degrades accuracy [1]. Fig. 1 shows contact state of the i^{th}-ball and grooves. α represents the contact angle of the ball and groove, D is the ball diameter. F_i denotes ball contact load, *etc*. Using the given parameters, Hertzian contact deformation constants between balls and grooves are derived through elliptic integrations [1]. Applying for compatibility and force equilibrium conditions, body deformation is estimated according to the assembly and load conditions. However, variation of the conformity affects the contact deformation significantly. Fluctuation of the contact angle generates uncertainty of contact deformation estimates [1-2]. In addition, it is difficult to measure the axial stiffness accurately because of measurement, material, and geometric uncertainties during experiments.

To perform uncertainty estimations of the nut stiffness in analytic and experimental processes, Monte Carlo simulation based on previous analytic models has been conducted according to Fig. 2. GUM evaluation of experimental stiffness measurement has been accomplished under various loading conditions [1-3]. In this paper, to improve uncertainty estimation accuracy through the MCM process [3], more accurate stiffness model considering contact angle variation between balls and grooves is to be applied for the analytic estimation. New loading and amended measuring units for experimental stiffness verification are to be applied for uncertainty evaluation by GUM [4]. Uncertainty verification between the improved mathematical model and experiments are to be conducted for several ballscrews, assembly and loading conditions.

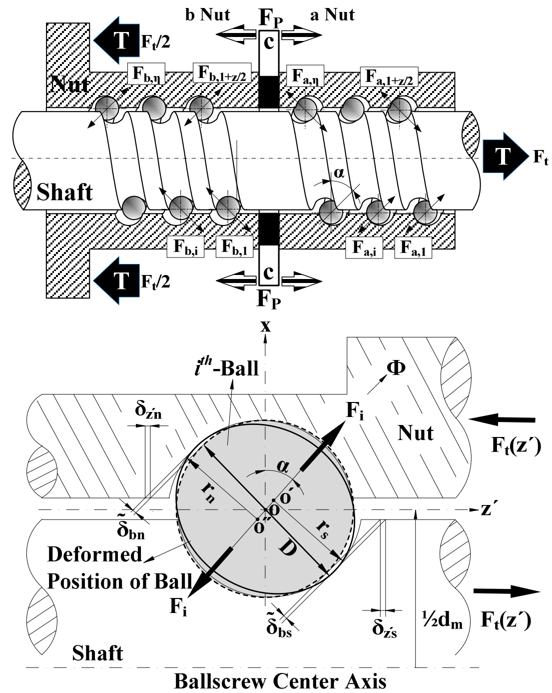

FIGURE 1. Double-nut ballscrew and contact mechanism.

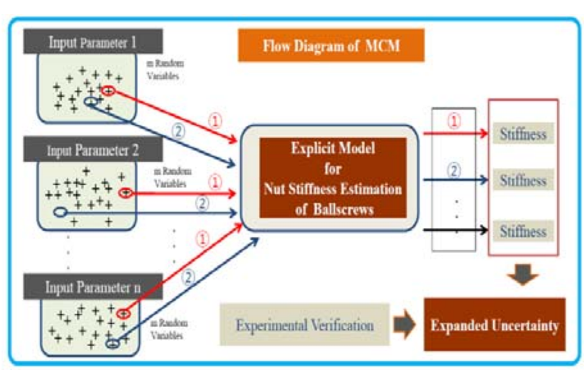

FIGURE 2. Uncertainty estimation by MCM [3].

UNCERTAINTY ANALYSIS

There are uncertainty factors in the stiffness measurement system. To obtain reliable results, experimental setup should be operated without uncertainty factors. Measurement system should have good linearity, resolution, repeatability, bandwidth, *etc*. Experts should conduct the experiments. However, it is impossible to satisfy these conditions in experiments. Although these conditions are applied in experiments, there are still uncertainty factors in measurement results. Therefore, uncertainty concept is needed to get reliable results from experiments.

Fig. 3 shows procedure of uncertainty estimation by GUM. Standard uncertainty is classified as A and B types. A type is a method of statistical evaluation from repeated measurement using t-distribution. Measurements of thrust force and displacement are classified as A type factors. Resolutions of the load cell and LVDT sensors, sensor setup errors, distortion of the loading unit, and thermal errors are to be evaluated as B type factors. Expanded uncertainty is to be estimated through the sensitivity analysis [3].

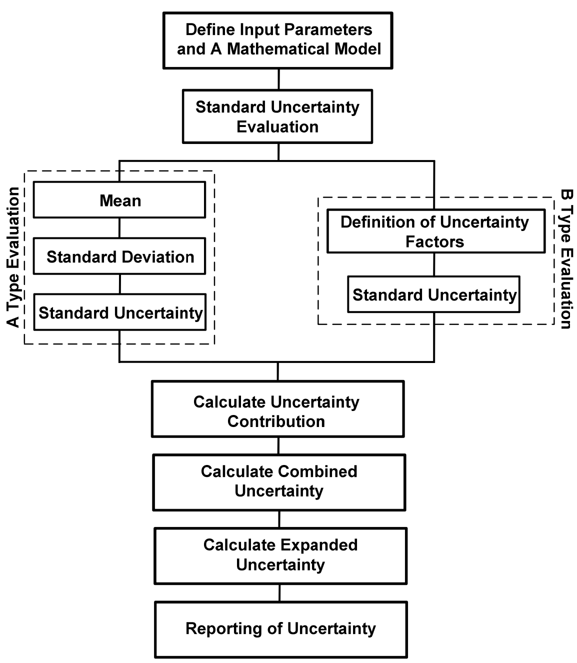

FIGURE 3. Procedure of uncertainty evaluation by GUM.

In this paper, experimental results are to be compared with the estimated stiffness by MCM. It will be confirmed that newly developed mathematical models generate more stable nut stiffness of ballscrews.

REFERENCES

[1] Chung S-C, Park C-H. Analysis of Ballscrew Stiffness owing to Contact Deformation in Leadscrew Systems. Proceedings of the ASPE 2010 Annual Meeting. 2010; 50:160-163.

[2] Chung S-C, Khim G, Park C-H. Precision Measurement of Nut Stiffness in Ballscrews. Proceedings of the ASPE 2012 Annual Meeting. 2012; 54:382-385.

[3] Min B-K, Cho H-G, Park C-H, Chung S-C. Modeling and Uncertainty Estimation of Ballscrew Nut Stiffness. Proceedings of the ASPE 2012 Annual Meeting. 2012; 54:394-397.

[4] Guide to the Expression of Uncertainty in Measurement, International Organization of Standardization (1995).